PHYSICS AND SOCIETY

Volume 20, Number 2 **April 1991**

The American Physical Society
335 EAST 45TH STREET
NEW YORK, NY 10017-3483

Non-Profit Org.
U.S. Postage
PAID
Rockville Centre
N.Y.
Permit No. 129

Physics and Society is the quarterly of the Forum on Physics and Society, a division of the American Physical Society. It presents letters and reviewed articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. Opinions expressed are those of the authors only and do not necessarily reflect the views of the APS or of the Forum. Contributed articles (2000 words maximum, technicalities are encouraged), letters (500 words), comments (1000 words), reviews (1000 words), and brief news articles, are always welcome. They should be sent to the editor: Art Hobson, Physics Department, University of Arkansas, Fayetteville, AR 72701, 501-575-5918, FAX 501-575-4580. Typist: Sandra Johnsen. Layout: Page Perfect of Fayetteville.

LETTERS

Israeli Ballistic Missile Capabilities

The letter by Alexeff and response by Fetter in the January 1991 issue reflect a small but significant educational problem. In discussing nuclear warheads, Alexeff writes of shells "weighing 43 kg", while Fetter uses the kilogram both as a unit of weight and a unit of mass.

Mass and weight are completely different quantities and so they have very different units. Mass is measured in kilograms. Weight is a force and hence should be expressed in newtons. The international documents which are the basis of the SI units go out of their way to be absolutely clear that the kilogram is not a unit of weight (force).

Students have struggled for decades with the problem. "Is the pound a unit of mass or of force?" The confusing answer is that it is both. When pound is the unit of mass, the corresponding force unit is the poundal. When the pound is the unit of force, the corresponding unit of mass is the slug. We don't want this unnecessary confusion to carry over into our usage of the metric system.

Let me request that the editor correct cases of incorrect usage of SI that may appear in manuscripts so that the educational value of our journal is increased.

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A Lunar-Energy SDI Conversion Proposal

My article (January 1991) contains a number of printing errors in its published form. To correct these, replace "a" by "α" in Eq.(2); "S" by "$\equiv$" in Eq.(4); "=" by "+" on the second line below Eq.(8); "v" by "V" and "$v = v_{t_-}$" by "$V = V_t$" for the integration limits in Eq.(8); "e" by "e" in Eqs.(2) and (5), and just above Eq.(10); "e_m" by "e_M" on the third line above Eq.(4); "R_m" by "R_M" just above Eq.(4); "v_m" by "v_M" in and just above Eq.(4) and on the third line below Eq.(8); "v^2_m" by "$v_M{}^2$" in Eq.(10); and "received" by "receiver" on the fifth line of the last column.

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A Radiation Unit for the Public

The public has an exaggerated fear of even small amounts of ionizing radiation, such as x-rays and radioactivity. The fear of radiation is made worse by not understanding the scientific words used to describe it. This article describes a radiation unit based on natural radiation that is easily understood by the public.

I propose a simple way to explain radiation. The quantity is called *ionizing radiation*, which will often be shortened to *radiation*. The new unit for ionizing radiation is time—"Background Equivalent Radiation Time" (BERT). BERT is the number of days, weeks, months or years that would give an adult the same "effective dose equivalent" from natural or background radiation. In calculating the BERT I suggest using an average background rate of 3 mSv (300 mrem) per year even though the background varies somewhat over the earth. (I thank my colleague Professor H.T. Richards for suggesting the name for the unit.)

In describing radiation to the public BERT would not be mentioned. The amount of ionizing radiation would be expressed simply in terms of days, weeks, or months of natural radiation. For example, compare the information in the following statements: "Your x-ray study gave you about 100 millirems or 1 mSv of effective dose equivalent;" or "Your x-ray study gave you radiation equivalent to about four months of natural radiation."

It is easy to use the new unit. You have to remember that natural radiation to the public is about 300 millirem or 3 mSv per year. Once you know the effective dose equivalent in mSv or mrem you can figure the days, weeks, months or years of natural radiation. For example, the BERT for 1 mrem is roughly one day of natural radiation and the BERT for 1 mSv is about four months. Radiation that strikes only part of the body, such as medical x-rays, is not as hazardous as the same amount of radiation to the whole body. For example, 100 mrem to your lungs is equivalent to only 12 mrem of effective does equivalent to the whole body. Other organs have similar factors to convert the dose equivalent to effective does equivalent.

Typical BERTs of ionizing radiation from medical x-rays with this new unit are: for a dental bitewing, about one week; for a chest x-ray, about ten days; for a mammogram, about three months; and for a barium enema x-ray study, about one year. The values vary greatly from one medical center to another. The BERT for the average amount of radiation to the public each year from diagnostic x-rays is about seven weeks. Of course, some people receive much more than others. The BERT for the average amount of radiation we receive each year from nuclear power plants is less than one day of additional natural radiation even for people who live in the vicinity of a nuclear power plant. The BERT for a trans-Atlantic jet flight is about five days.

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ARTICLES

Stability Through a Comprehensive Ballistic Missile Flight-Test Ban

Robert Sherman

U.S.-Soviet tension has virtually disappeared, and the danger of global nuclear war appears to have gone with it. But leaders and policies can change rapidly. Should psychologically insecure militaristic leaders come to power on either or both sides, they would have at hand the same destabilizing and massively destructive strategic nuclear power as their Cold War predecessors. The risk of nuclear annihilation would return.

How can this be avoided?

Rapid disarmament is not in the cards, due to the extreme difficulty of verifying small numbers (tens) of clandestine strategic nuclear weapons, combined with the political advantage such a force would present against an opponent having no nuclear weapons. Neither is effective strategic defense probable within the next few decades, for reasons familiar to every reader of this journal.

Rapid disarmament is not in the cards.

The only solution is deterrence by threat of retaliation—that is, bilateral dominance of retaliatory capability over first-strike capability. To determine the best means of maximizing deterrence, I suggest a three-step process. The first two steps may seem so conventional and noncontroversial as to be hardly worth stating. But they lead inexorably to a third step which deviates widely from past and present arms control practice.

Identify the assets that deter attack

These are manned bombers on ground alert, ballistic missile submarines on station or in transit, ICBMs in silos, and the command, control, and communication (C^3) needed to make them work. In addition, the Soviet Union already possesses mobile ICBMs, and the United States may acquire these in the future.

Identify the threats that could disable those assets

These are the villains of the piece. The strategic nuclear weapon properties which most directly threaten to enable first strike and undermine deterrence are:

- *Accuracy* to destroy hard silos and hard C^3.
- *Surprise* (less than 7 or 8 minutes' warning) to destroy unlaunched, bombers soft C^3, and mobile ICBMs. Lesser surprise capability (about 15 minutes' warning) can, if combined with accuracy, destroy silo-based ICBMs before they can be launched under attack.
- *Warhead/silo ratio above 2:1* to enable an ICBM counterforce exchange to disarm the victim more than it disarms the aggressor. As a rough approximation, a disarming first strike requires aggressor two warheads (to compensate for inaccuracy and/or unreliability) per enemy silo or other strategic-force high-value target, plus a third warhead for research and/or lower value targets.
- *Strategic anti-submarine capability* to pre-empt against that leg of the victim's triad.
- *Weapon reliability* to give the aggressor confidence in his ability to minimize retaliation. Since the retaliator has an easier mission—his targets are fewer, softer, and not time-urgent—he needs less reliability than the aggressor. Thus, high weapon reliability shifts the balance away from deterrence and toward first-strike aggression.

High weapon reliability shifts the balance away from deterrence and toward first-strike aggression.

All five villains must be on line for a disarming first strike. While elimination of only one of the five would be sufficient to deter rational leadership, national leaders are not always rational leaders. Thus, the larger the number of first-strike ingredients that can be limited, reduced, or eliminated, the lower the probability of strategic nuclear war.

Seek means to control those threats

SALT I and SALT II are useful in other ways, but have negligible impact on any of the five villains. START, as it is presently formulated, does no better. The only villain it even seeks to address is warhead/silo ratio, and it does this in an ineffective way, leaving the probable ratio above 4:1.

A better solution is to move directly into negotiations for START II. This could be done by shuttling down START I, which in any case seems deadlocked over secondary issues, or by opening a START II track while continuing to seek completion of START. The latter course is probably more politically palatable, particularly on the Soviet side. But wat should START II, or any related agreement, consist of?

SALT has negligible impact on any of the villians. START does no better.

We can divide the possibilities into three categories.

Temporary palliatives may be desirable. But it is fair to ask if they are worth the immense time and effort which must go into any ratified arms control agreement.

Paul Nitze argues for abolition of the SS-18 and MX forces. This would remove the most accurate missiles now in existence and would marginally lower the warhead/silo ration. But its benefit would disappear as the accuracy of Minuteman 3, Trident

The author is on the staff of the U.S. House of Representatives.

1 and 2, SS-19, SS-24, SSN-20, and SSN-23 progressively improved.

Senate Armed Services Committee Sam Nunn recommends abolition of all land-based MIRVs. This is, in essence, the Nitze plan taken a step further. As with the Nitze plan, its excellent near-term benefit would degrade as SLBM accuracy improved. We need more enduring solutions.

Single-benefit permanent solutions are far more beneficial. Military technologies have a way of breaking out in unexpected an destabilizing ways. Any door we can close for good may prevent problems we can't even anticipate at the time; the 1972 ABM Treaty, which closed the door on SDI, is the best example of this. In the unlikely event that a prohibited technology should develop unambiguous and persuasive net stabilizing ramifications, the treaty can always be revisited.

A Comprehensive Test Ban on nuclear test explosions would permanently lower weapon reliability, and is desirable for that reason.

A total MIRV deployment ban, on SLBMs as well as ICBMs, would eliminate the warhead/silo ratio villain—assuming numerical parity.

A flight test ban on depressed trajectory and other short time of flight (STOF) ballistic missiles would permanently eliminate a major component of surprise attack. A flight test ban on anti-satellite weapons would eliminate another component of surprise attack. The former has been proposed by the United States; the latter has been proposed by the Soviet Union. Each side should accept the other's offer, but has not.

Multi-benefit permanent solutions, in which one agreement would cure several problems, would be still better. But there appears to be only one arms control concept that would, at one stroke, attack more than one villain. This is a Comprehensive Ballistic Missile Flight Test Ban (BMFTB).

There appears to be only one concept that would attack more than one villian: a Comprehensive Ballistic Missile Flight Test Ban.

Since new guidance or re-entry technologies could not be certified in the absence of flight testing, the BMFTB would cap accuracy near its present level. By including a STOF flight test ban, the BMFTB would prevent the most dangerous potential increase in the threat of surprise attack. And in the absence of flight testing, missile reliability would progressively decline.

Commonly-raised objections to a BMFTB

Let us now briefly examine two commonly-raised objections to a BMFTB.

Isn't ballistic missile accuracy already so good that there's no stability benefit to be gained form capping it? No, although the benefit is less than it used to be. Against an SS-18 Mod 4 attack, it is possible to get excellent ICBM survivability by modest-cost silo hardening. Against an SS-18 Mod 5 or a Trident 2 attack, survivability by hardening would be considerably more costly; against an MX attack in which the accuracy is comparable to the crater radius, survivability through hardening would be very expensive or impossible. Five years ago, the BMFTB accuracy cap could have stood alone; now it would work significantly better if combined with a low numerical limit or total prohibition on the most accurate existing MIRV ballistic missiles.

A BMFTB combined with the Nitze MX/SS-18 ban or the Nunn MIRV ICBM would be highly synergistic, with the type ban solving the problem of existing missiles and the BMFTB solving the problem of future missiles. If, as seems probable, the Soviets were to insist on a ban or low limit on Trident 2, the U.S. could insist on reciprocal constraints on SSN-20 and SSN-23. The only remaining MIRV missiles—Minuteman 3, Trident 1, SS-17, SS-19, SS-24, and SSN-18—would be well short of silo-killing lethality, and would be unable to get it without further flight testing.

Can't an aggressor deploy and use accuracy upgrades without testing them? Yes, but at the sacrifice of reliability. Net first-strike damage expectancy would be more likely to fall than to rise under such a strategy.

In a world of zero-benefit and single-benefit strategic arms control proposals the triple-benefit BMFTB stands alone. But improvements in ICBM and SLBM accuracy are gradually eroding its potential. And while STOF development does not appear to be under way on either side, there is no guarantee that this will not change. Stability would best be served by a BMFTB sooner rather than later.

REVIEW

Conventional Force Reductions: A Dynamic Assessment, by Joshua M. Epstein. The Brookings Institution, Washington, D.C., 1990, 275 pages

Physicists were present at the creation of nuclear war, and so it is not surprising that intricate mathematical analysis (based upon real data) had evolved as part of the lore of nuclear warfighting. Critics may doubt the significance of this work should war actually come, but there is no doubt that analysis has played a role in policy studies and, to some extent, in policy. In contrast, conventional warfare antecedes physics, and analysis of conventional warfare is far more rudimentary.

While scientists, at least since Archimedes, have been builders of weapons, the first influential analysis of the prosecution of conventional warfare—more precisely, the prosecution of battle—was that of Frederick William Lanchester, an English engineer who wrote around the time of World War I. Lanchester's equations state that in an exchange of fire between two sides ("red" and "blue"), the rate of loss of reds is proportional to the number of blues, and vice versa:

$$-dR/dt = bB$$

$$-dB/dt = rR$$

Scientists, at least since Archimedes, have been builders of weapons.

The constants r and b represent the effectiveness of the firepower of R and B, respectively. Historically Lanchester's equations express the emergence of weapons accurate enough so that each soldier firing a gun may be assigned a fixed probability (per shot or per unit time) of hitting his target. The solution of these equations have some interesting consequences, notably the fact that the appropriate measure of the "strength" of a fighting force is rR^2; numbers are more important than technical capabilities. (It is easy to see that the quantity $rR^2 - bB^2$ is a constant of the motion. Thus R "wins" if $rR^2 > bB^2$ at t = 0, where winning means that R(t) is still positive at a time when B reaches 0.) The equations imply also that a weaker force can overcome a stronger force by dividing the enemy, and defeating portions of it in separate battles.

The Lanchester equations can be generalized to describe encounters involving several types of weapons (tanks, artillery, aircraft), albeit with an increasing number of uncertain parameters. And these generalized equations have played a part in military and civilian analysis of potential conventional warfare for many years. There is, however, little in the way of experimental corroboration of the theory, in the form of fits to attrition rates in historical battles.

Lanchester theory makes no distinction between offense and defense, only superficially takes account of tactics, and recognizes no diminishing marginal utility in crowding more and more forces within firing range of the enemy. This last points up the fundamental flaw in the theory, the lack of space dimensions as variables (dependent or independent) in the dynamical description of warfare. In response, Joshua Epstein, an analyst at the Brookings Institution, had developed a new model for a conventional battle, which allows for movement of forces.

Epstein focuses on a defending commander's option, in the face of heavy casualties, to withdrawal from the front. In his model, the defender's withdrawal rate, W(t) (in km/day), is determined by his casualty rate, $\alpha_d(t)$, (fractional losses per day), a threshold casualty rate, α_{dT}, and the maximum possible withdrawal rate, W_{max}. When $\alpha_d(t) > \alpha_{dT}$, W can increase according to

$$dW/dt = (W_{max}-W)(\alpha_d-\alpha_{dT}) / (1-\alpha_{dT})$$

But when $\alpha_d(t) < \alpha_{dT}$, W is set equal to zero. An increasing value of W feeds back to reduce the casualty rates, α_d and α_a, of defender and attacker respectively. In a third feedback loop, the casualty rate suffered by the attacker determines the rate at which he prosecutes the battle, and thus affects the casualties of both sides. (It is intended that the attacker's prosecution rate increase or decrease according to whether his casualty rate is below or above a threshold, α_{aT}, although the equations will not act this way in all cases.) The model is thus characterized by *adaptive* behavior on both sides.

Other important time-dependent variables introduced in these equations are the ground casualties inflicted by close air support (treated differently from ground-to-ground casualties), and the rate at which reinforcements are introduced. In an earlier book (*Strategy and Force Planning: The Case of the Persian Gulf*, Brookings 1987) Epstein employed his model to analyze hypothetical battles between US and Soviet forces in Iran, finding authorities in the US to be, characteristically, unduly pessimistic about US conventional capability. The significance of such estimates, however unreliable they may be, goes beyond the outcome of the battle. For the nation that cannot count on its conventional force is likely to plan for and lean toward escalation—including the threat or use of nuclear weapons.

The nation that cannot count on its conventional force is likely to lean toward escalation —including the use of nuclear weapons.

This same tension between a presumedly weak conventional defense and the threat of nuclear escalation held center stage in the NATO-Warsaw Pact confrontation that dominated foreign affairs for 40 years. This confrontation, despite its being perhaps of only historical interest, is the subject of the present book. The Warsaw Pact barely exists, and the invasion from the East seems fanciful. Nonetheless, NATO will maintain 20,000 tanks and

close to 200,000 troops in Europe under the (about-to-be-signed) CFE treaty, and behind the formulation of reductions to these levels lies some model of potential warfare. This book endeavors to provide a more realistic model.

A variety of calculations are shown using as input, (a) the current (late 1980s) forces, (b) the forces following unilateral cuts in the East, (c) forces expected under the CFE Treaty, and (d) forces 50% below CFE. NATO wins in all cases. Interestingly, Epstein also poses a "worst case scenario," to test the robustness of NATO defense when the attack is concentrated: the Warsaw pact shifts 60% of its force to the southern sector. In this scenario, NATO loses with the present force, but wins with the CFE force.

The drastic misallocation of defensive forces on the battlefield represent a failure in intelligence rather "dexterity," the ability to move forces rapidly from the south to the north, i.e., in a direction parallel to the front. Thus these "60/40" calculations point to a key feature of conventional battle, which Epstein has recognized, but not modelled dynamically. One might say that while Epstein improves on the Lanchester equations by modelling the space dimension perpendicular to the front, a fuller treatment of battle awaits a dynamical model in two dimensions, those parallel and perpendicular to the front.

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NEWS

Global Warming at the Washington Meeting!

The Forum on Physics and Society, the APS Panel on Public Affairs, and the Program on Science, Technology, and International Affairs of the Georgetown University Department of Physics will jointly sponsor a weekend topical meeting on global warming. The meeting will precede the APS Spring meeting in Washington, DC. If will be held on Friday evening, Saturday and Sunday, 19-21 April, at the School of Foreign Service, Georgetown University, Washington, DC.

Is global warming here or not? What are the data? How reliable are the computer models that predict it? Such questions continually surround the issue of climate change. This short course is intended to give physicists and other interested parties the in-depth technical background needed to evaluate fully the scientific issues. The short course will also include various policy implications.

The conference is being organized by Barbara Levi of *Physics Today*, and David Hafemeister of the US Senate Foreign Relations Committee. The $100 registration fee includes a book that will be made from the conference proceedings and from other papers.

Friday 19 April, 08:00-09:30

- Richard Benedick, former US Chief Negotiator, Montreal Protocol on Ozone Protection: Environmental diplomacy: new directions in safeguarding the planet

Saturday 20 April, 08:30-12:30: Atmospheric physics and chemistry

- Tom Ackerman, Penn State: Optical processes in the atmosphere
- Jagadish Shukla, University of Maryland: Basic introduction to climate modeling
- David Randall, Colorado State: Global climate models
- Robert Cess, SUNY, Stony Brook: Comparisons of GCMs

Afternoon session, 13:30-17:30: Evidence for climate change

- George Maul, NOAA, Miami: Temperature records
- George Maul: Sea level rises
- V. Ramanathan, UC San Diego: Satellite data and what it tells us about feedbacks and theories
- Wally Broecker, Lamont Doherty Observatory: Ice ages and CO_2 levels

Sunday 21 April, 09:00-noon: Sources and sinks of greenhouse gases

- Mark Trexler, World Resource Institute: Biological carbon cycle, deforestation, reforestation
- James Kasting, Penn State: Geochemical carbon cycle
- Donald Blake, UC Irvine: Other greenhouse gases

Afternoon session, 13:30-16:30: Possible remediations and mitigations?

- Rob Coppock, National Academy of Sciences: Policy implications
- Rosina Bierbaum, Office of Technology Assessment: Possible means to reduce CO_2 emissions
- Art Rosenfeld, Lawrence Berkeley Lab: Options for reducing emissions

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REGISTRATION

NAME _____

ADDRESS _____

_____

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☐ $100 enclosed (includes proceedings)

☐ $40 enclosed (student, no proceedings)

Mail to David Hafemeister, 3304 McKinley, NW, Washington DC, 20015 (202-224-4447, home 202-244-2070)

Call for Nominations for APS Fellows!

Send your nominations for new Forum-sponsored APS Fellows, with supporting material, by 1 September 1991 to Michael Sobel, Physics Department, Brooklyn College, Brooklyn, NY 11210.

This year's newly elected Forum-sponsored APS Fellows are:

- Lew Allen "For contributions to the nation through extensive service to the furthering of national goals in space exploration."
- Gene I. Rochlin "For a broad range of studies in technology and society, especially those on nuclear-fuel cycles and related issues of spent-fuel handling and nuclear proliferation, and those on the behavior of institutions in the face of technical issues."
- Peter D. Zimmerman "For analysis and participation on nuclear arms issues in the START talks and in the public sector."

Congressional Day!

The APS physics planning committee has announced that it will sponsor a "congressional day" during the Washington APS meeting this April. The committee intends to bring together approximately one hundred physicists with several hundred Congressmen and their staff members during a day-long event on Capitol Hill on Thursday, April 25th. Through face-to-face discussions to be held in individual Congressional offices, the planning committee hopes to raise the awareness of Congress to the desperate state of American science. The planning committee believes that the vital economic and security interests of the

United States will be jeopardized if strong federal action is not taken soon to remedy the precipitous decline in effective support for basic scientific research and graduate education.

The APS Office of Public Affairs will organize the volunteer physicists into regional teams, appropriately balanced according to scientific disciplines. For each team, the committee will schedule a series of meetings with several members of Congress who represent the team's region and several members who serve on House or Senate Committees that have jurisdiction over science policy and science funding. Each team will be provided with statistical material and briefing documents for distribution to Congressional offices. Individual team members will be expected to describe their own experiences in science research, education, and professional life in words that can be understood by nonspecialists. The team members will present their own insights into the importance of science to the future of the country.

The schedule of planned events includes a briefing and "pep rally" at 5 pm on Tuesday, April 23rd at the Ramada Renaissance Tech World Hotel featuring Senator Albert Gore, Jr. of Tennessee and an evening reception on Thursday, April 25th in the Rayburn House Office Building hosted by Congressman George Brown, Jr. of California. Physicists and Congressional staff members who wish to receive additional information about Congressional Day or who wish to participate in the activities should contact Dr. Tina Kaarsberg at the APS Office of Public Affairs (Telephone 202-232-0189, FAX 202-328-3729, BITNET TMK@AIP) as soon as possible.

APS Congressional Day, schedule of events:

Date	Time	Description	Location
23 April 1991	17:00-18:00	Briefing and pep rally featuring Sen. Al Gore (D-TN)	Conference hotel, rm. 7 BA
25 April 1991	08:30	Volunteer physicists gather, pick up last minute info, coffee and bagels	Conterence hotel lobby
25 April 1991	09:30-17:00	Visits to members of Congress	Hill
25 April 1991	17:00-19:00	Reception hosted by George Brown, Jr. (D-CA)	Rayburn House Office Building room 2318

Thanks for the Old Newsletters

In the January issue, the editor sent out a call for old newsletters in order to complete the newsletter part of the Forum's institutional memory. An enthusiastic "thank you" ("thanks for the memories?") goes out to the following individuals, each of whom sent several back issues to the editor: Jan M. Engel, E. B. Montgomery, John M. Charap, Edward Petersen, Kent Harrison, William B. Herrmannsfeldt, Kenneth W. Ford, George R. Ringo. The contributed issues have not yet been sorted through, so it isn't clear whether our institutional memory is now intact.

To Receive *Physics and Society!*

Physics and Society, the quarterly of the Forum on Physics and Society, a division of the American Physical Society, is distributed to members of the Forum and to physics libraries. Nonmembers may receive the newsletter upon request by writing to the editor; voluntary contributions of $10 per year are most welcome. Make checks payable to the APS/Forum.

Physics libraries may receive *Physics and Society* free upon request by writing to the editor. The Forum hopes that libraries receiving *Physics and Society* will archive it. Forum members should request that their libraries do this.

If you are an APS member it is easy to join the Forum and receive *Physics and Society*. Just complete and mail (either to the editor or directly to the APS office) the following form, or mail us a letter containing this information.

I am an APS member who wishes to join the Forum:

NAME (print) _____

ADDRESS _____

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COMMENT

Editor's note: The Gulf War has turned out to be controversial for the Forum. In fact, when a preprint of this issue's editorial was circulated among several Forum members, it reportedly raised a "firestorm of controversy." One issue is that of the Forum's proper role. The first article below is based on a letter from Forum Chair Thomas Moss to Professor Nina Byers of the UCLA Department of Physics, responding to a telephone conversation concerning the proper role of the Forum in increasing understanding of the war. The second article gives the view of the three members of the Forum's newsletter advisory committee. The third and fourth articles present pro and con views of Operation Desert Storm.

The following aspects of Physics and *Society* editorial policy (first stated in the July 1988 issue) should be noted: 1. Editorials, comments, letters, reviews and articles do not represent the opinion of the Forum or of the APS. Editorials (especially the one in this issue!) are of course the editor's opinion alone. 2. Articles should be grounded in physics and/or its history or philosophy and should not contain strong elements of opinion. 3. Controversy can be creative. Thus, letters and comments may be opinionated, debate is welcome, all views are welcome, and dissenting opinions are especially encouraged. 4. The views in letters and comments are a result of the items submitted. Thus, balance is not guaranteed. Readers who object to any perceived bias may correct this by submitting something on the other side.

The Gulf War: What Role Should the Forum Play?

The total explosive force used in the war already approaches that of a minor nuclear exhange—and certainly exceeds that which we considered to be a substantial nuclear exchange when the APS first became active in nuclear arms control.

Questions : Can we [the Forum] get accurate unclassified data on the scale of the Gulf bombing and its impacts? Can/ should we translate that into terms understandable to the public and APS membership? Are there groups such as FAS also focusing on this, with whom we might work in a cooperative effort?

Clearly modern physics has contributed much to both the design and delivery systems of the weapons used in the Gulf War, and some physicists have special knowledge in understanding their capabilities.

Question : Should we be addressing control of this form of armament with the same intensity we have been focusing on nuclear arms control in the last decade?

Given the well-known impatience of the US political system, there is clearly a risk that stalemate in the Gulf War will lead to pressure for use of tactical or strategic nuclear weapons.

Questions : Should the APS and/or Forum be calling public and APS membership attention to such scenarios?

When we accumulate some input [from the Forum Executive Committee, regarding the above questions], we'll distribute it and focus on what action to take. I appreciate your effort catalyzing us on this. We'll see what comes out of the effort.

Thomas H. Moss, Forum Chair
Dean of Graduate Studies and Research
Case Western Reserve University
Cleveland, OH 44106

The Gulf War: The Forum's Proper Role

Since August, Americans have watched the events in the Middle East with great intensity and emotional involvement. Physicists are no exception. Whether or not we as individuals concur with the policies being pursued, the actions will have far-reaching impacts. A few Forum members have called for this organization to become involved in the issue of war and peace in the Gulf. Before we let our present high emotions carry us into inappropriate territory, we should pause for a look at the terrain. Just like soldiers stepping through a mine field, the Forum should be careful where to tread.

We feel that two principles should govern the Forum's conduct: The first is to choose issues that have a higher technical than political content. It is only on technical matters that we as physicists have some special expertise to contribute. For example, when the "Star Wars" issue was raging, a POPA study group wisely limited itself to the narrow question of the feasibility of developing the weapons, and not to the wider strategic, political and economic questions regarding the wisdom of the program itself. As a result, the study had high credibility and made a big impact. The second principle is that, on controversial issues, all responsible sides of any issue must get equal space in *Physics and Society* or equal time at APS invited-paper sessions.

There are, in fact, technical issues emerging from the recent Gulf War that warrant attention from Forum members:

- *High-technology weapons*. Precision-guided munitions and surface-to-air missiles became real heros to the American public during this war. The balance of attention has now shifted from nuclear to conventional weapons. Which weapons should be emphasized in future defense appropriations, and how should they be used in future conflicts? Can the export of high-tech weapons be controlled?
- *Proliferation*. President Bush has expressed great concern about the potential capability of Iraq to develop nuclear weapons, and Iraq's nuclear facilities were early targets of the Allied bombing. Other nations have been inching closer to a nuclear weapons capability. It's time to substantially increase our attention to this threat, as well as that posed by chemical and biological weapons and the missiles that deliver them.
- *Energy*. Concern over the supply of Mideast oil was a large motivating factor in the Gulf War. The war dramatically underscores the need for a hard look at energy use both in the US and abroad (as if global warming hadn't already raised enough concern—see the announcement about the short course on global warming on page 7). The Forum has sponsored a study group on energy, and the resulting book is in press. But this issue warrants continued attention.

The Forum has worked hard to establish a reputation for sponsoring balanced and responsible debate on a spectrum of topics. We urge the Forum to continue participating in the most constructive fashion possible.

Barbara G. Levi
David Hafemeister
Richard Scribner

The Gulf War: An Appropriate Use of Physics

A justifiable war

The defining event of 1990 will be the global response to Iraq's invasion and subsequent rape of Kuwait. Rarely has the world community been so united in expressing the belief that not only are there some things worth dying for, but that there are also causes worth killing for. With the lessons taught in Europe by Germany from 1933 to 1939 and those taught in Asia by Japan during the same period well in mind, the UN Security Council took action to ensure that aggression would not be rewarded with either booty or territory. The resort to armed force is usually justifiable only after all possible peaceful solutions have been exhausted, but in the 1990-91 war in the Persian Gulf, no opportunity for a genuinely peaceful remedy arose.

Economic sanctions were tried, but the embargo leaked like a sieve through Jordan, as munitions captured on the battlefield showed. It would have taken many more months, perhaps years, to force Iraq to capitulate. In the intervening time still more Kuwaiti citizens would have been carted off to Baghdad, and still more of Kuwait's infrastructure would have been looted.

One may even question whether Iraq's dictator could psychologically have backed down without a military defeat. The change in Iraqi bluster and behavior between the time the air attack began and the time when the ground war ended may well indicate that Saddam Hussein could accept honorable defeat in battle more readily than he could accept humiliation on the diplomatic front.

Make no mistake: the Gulf War was about oil. If Kuwait had not been oil-rich, the Iraqi government would have had no interest in acquiring an additional few thousand square kilometers. If it had not been dangerous to leave a large fraction of the world's petroleum reserves in the hands of a thug such as Saddam Hussein, it would have been difficult to assemble a coalition to repulse his aggression. But the United States was able to act in defense of global interests because Kuwait was accessible. Bases could be established in Saudi Arabia, which itself needed to be defended; ships could ply the Gulf's waters to bring in heavy supplies; and modern airfields were already built at Dharan and elsewhere.

Other nations have been brutally repressed and occupied in recent years, and the moral case for giving them our assistance may even have been greater than it was for Kuwait. Unfortunately for us and for them, the geography and politics of their situations tilted against the use of American armed force, although American force was responsible, at least indirectly, for terminating the Soviet occupation of Afghanistan.

The role of physics

The Gulf War was won with a minimum of casualties on both sides thanks, in part, to the success of solid state physics over the past decades. From the development of radar-absorbing and deflecting materials to the construction of the brains of smart weapons, allied forces relied on advanced technology for the precision weapons to attack small military targets even when they were surrounded by civilian facilities.

The images of dead Iraqi civilians which were burned into American consciousness come, largely, from two attacks: the destruction of an air-raid shelter which probably was — or probably wasn't, depending upon who is speaking — in fact a command and control site, and from the errant British guided bomb which landed in a market square. To be sure, there were more civilian casualties in Iraq than that, but the precision of the allied weapons kept the toll within bounds.

Smart bombs do not strike their targets every time, and indeed a reasonable inference from the number of sorties flown against the bridges over the Tigris and Euphrates is that perhaps only 20% of them hit the mark. Compared to the 1-2% of "dumb" iron bombs that get close to their aim point, that is fantastic. But the real benefit to civilians from smart weapons is the reduction of the average miss distance from hundreds of meters to tens of meters. The effect is, first, a smaller percentage of the explosives falls in the vicinity of civilians than before because there is no need to use carpet bombing tactics against hardened targets; second, the total amount of explosives needed to destroy a target is far smaller than with conventional munitions so that far fewer bombs are used than before.

Solid state physics has made possible the new tactics that permit an air force to strike military targets with something approaching real precision. I had the chance to speak at length with Bernard Shaw and John Holliman of CNN, two acquaintances who reported the first night of the air war from their hotel in Baghdad. It was clear to them that they were in no danger except for debris from falling antiaircraft shells, because they could observe the precise points where American weapons exploded. They knew the Baghdad skyline and could say (after leaving Iraq) that essentially every detonation was on or near to a legitimate target. As I left the CNN studio in Washington after being properly skeptical of high-tech weapons, Bernie Shaw's last comment was that I shouldn't let anyone tell me that there was no such thing as a surgical strike: He had seen hundreds of meticulously executed attacks over many nights of watching. Other correspondents in Baghdad remarked obliquely in their censored reports that they had to be driven long distances to find a very few civilian areas destroyed by allied attacks while flattened military installations were to be seen everywhere.

There is no joy in killing or enabling another to kill, and rarely any glory in the job. But occasionally there are just causes for going to war, and just wars to fight. An important component to waging a just war is the protection of innocents. In the Gulf physics enabled our armed forces to extend just such protection to Iraqi civilians. From Archimedes to Oppenheimer physicists have been leaders in providing governments the military tools needed for defense. Often those tools have been blunt instruments of greater and more random destruction, but in the Gulf War they became precision instruments permitting the destruction of military power with reduced loss of innocent lives. For this we can be grateful.

Our profession has made it possible to destroy the military power of an international bully without simultaneously subjecting innocent people to the kind of pounding inflicted on Coventry and Rotterdam by the Luftwaffe or on Dresden by the British and American air forces.

The nuclear option

In Washington it was clear that the nuclear option was at the back of everyone's mind. Serious students of strategy, arms control experts with decades of experience, continually asked me "Can we beat this guy without using nukes?" For six months I answered with a cautious "yes, if —." If Saddam did not use poisonous gases in massive amounts which demanded an escalation of violence; if the ground war did not degenerate into World War I-style trench warfare; if the precision munitions, most of which date from the Carter administration or before, really worked as designed; if the bacteriological sword forged at Salman Pak on the Tigris stayed in its scabbard.

However, very little attention has been given in the unclassified (and probably in the classified) literature to a direct and quantitative analysis of the capabilities of "improved conven-

tional munitions" to do the job of tactical nuclear weapons. Indeed, in the last decade there has been very little thought given to the question of whether or not tactical nuclear weapons have any role to play in war at any level. Looking back on work done in the early 1980s and studying the results in the Gulf, it may be possible to say that there is no militarily useful tactical role for nuclear weapons that precision weapons and fuel-air explosives cannot do better, cheaper, and with less chance of losing control of the war. But I do not know with certainty that this is anything but a prejudice or a misconception.

Suggestion: a new Forum study

Little recent work has been done on the socially significant physics-related topic of the comparison of tactical nuclear weapons with modern conventional weapons. The Forum can play a most useful role here. The Forum energy study is complete, and it is time to find a new topic to engage our members. Ruth Howes, the incoming Chair, and I propose to begin such a project this Spring and invite volunteers willing to work long hours for no pay. In keeping with Forum tradition, all are welcome to participate, but only those who work will be considered active members of the study group. The effort will be impartial, independent, and non-partisan. It must address real US security and defense needs in a quantitative and objective way.

Potential study group participants should write to me or to Ruth with a description of their background, interests and previous expertise in the area. PZ's address is below. Ruth Howes can be reached at the Department of Physics and Astronomy, Ball State University, Muncie, IN 43706.

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Editorial: An Inappropriate Use of Physics

A personal note

I recall my first serious thoughts about the power of science. I was perhaps twelve, it was perhaps 1946, I watched Fourth of July fireworks from my parents' car. By coincidence the car radio was recounting 6 August 1945. As the rockets glared red and Hiroshima entered my young brain, I was transfixed by the tragic energies of America and science.

I did not know then, and I do not know now, whether Hiroshima was an appropriate use of American and scientific power. I do know that it was a seminal event, and sadly, the defining event of our century.

My first love was music, but my talent lagged and I turned to physics, to learn universal truths. I still believe that the search for natural truth is the highest human calling. And yet — and yet — pure physics has conferred irresistible power upon America at a time when America lacks the maturity to handle it.

We scientists must concern ourselves with such matters. It will not do to argue that physics itself is value-free, that human applications are not our department. It will not do to argue that scientists must restrict their vision to science. As quantum theory attests, there is never just "one thing": the one thing is everlastingly defined by all the other things. And as pragmatists, perhaps we can agree that the world will simply not work if we all take the attitude that the moral consequences of one's profession are not professional responsibilities. Thus, physicists must take stands on the great science-related moral issues. Einstein took such stands, for example by joining a very small minority of Germany's prominent intellectuals during World War I in signing a controversial petition opposing his country's involvement in that war. So did Sakharov, for example in 1968 when he published his wide-ranging controversial anti-government essay "Reflections on progress, peaceful coexistence and intellectual freedom." And so should all thoughtful scientists.

To put it another way: physics is moral and political. Scientists must take account of the moral and political ramifications before, during and after the physics.

A disastrous decision

The Gulf War enacted my worst fears: the confluence of the country I love with the physics I love in an action of unprecedented power, irrationality, and hubris.

Our President's November 8 escalation from Desert Shield to Desert Storm was arguably the most disastrous US decision of recent history, certainly more dangerous than the decision to enter the Vietnam War, and comparable with our 1938-41 mistake *not* to face Hitler in Europe. The risks were grossly disproportionate to the likely gains. The decision flew in the face of the observable data and rational analysis, and harmed America's true interests. The decision could not have been made absent America's possession of the physics-based technology of modern warfare. As an American and as a scientist, I protested visibly throughout the war, and I protest now although less visibly since the killing has stopped.

Among the multiple and mostly spurious justifications for the war, one honest motive rings clear: US control of Mideast oil.

Among the spurious reasons is the notion that the war was fought for Kuwait's sovereignty. But then why didn't we send half a million troops to battle the Chinese takeover of Tibet, the Soviet invasion of Afghanistan, the Soviet re-invasion of Lithuania, the Libyan occupation of Chad, the Syrian invasion of Lebanon, the Israeli attack on Beirut, the continuing Israeli attacks on Lebanon, the Indonesian invasion of East Timor, —? Indeed, did the US itself respect the national sovereignty of Cuba, the Dominican Republic, Libya, Nicaragua, Grenada, Panama?

And we did not go to war because Hussein is murderer and a thug. There are lots of thugs in the world, many of them on our side, and we can't police them all. The Reagan/Bush administration in fact sided with Hussein during 1980-90. And on the eve of the takeover of Kuwait, US ambassador April Glaspie, hearing Hussein state that an invasion could not be ruled out unless Kuwait yielded to some of his demands, uttered the immortal words "We have no opinion on the Arab-Arab conflicts, like your border disagreement with Kuwait."

Some Middle East experts carry this argument further. Joyce Starr, senior associate at the Center for Strategic and International Studies and author of *Kissing Through Glass*, a new book on US-Israeli relations, believes that the Glaspie statement was intended to give Hussein a green light to invade Kuwait so that the administration would then have a provocation to send troops to the Gulf.

Another thug, Assad of Syria, supporter of the Pan Am 103 terrorists and the US marine barracks bombing in Lebanon, is our ally. The Saudis torture such political enemies as the Yemenis. Libya, Burma, North Korea, Argentina, Chile, South Africa, and China have all been run in recent years by thugs. Shall we send our troops against them?

Reportedly, Bush's bottom line is the so-called Munich argument: If we didn't face up to Hussein now we would have to fight him later when he is stronger. But the facts are quite opposite to this argument. The presence of a world superpower, and the

Desert Shield deployment and blockade, were precisely contrary to Europe 1938-39. And as six former Secretaries of Defense and two former Chairmen of the Joint Chiefs of Staff testified last Fall, Desert Shield was working. We should have stuck with it.

The war was overridingly about oil. This was certainly clear e.g. to Bush's Secretary of Commerce Robert Mossbacher, who stated "Of course it's about petroleum. Crass or not, it's oil that keeps everybody going."

Oil is not worth the price. Far better than a war, the solution to Mideast oil instability is an energy strategy to largely unhook ourselves from oil imports, and "green taxes" to raise fuel prices ($6 per gallon, mostly taxes, is common in Europe). For a simple example, if we restore the automobile mileage standards that were rolled back during the 1980s, the US car fleet will get four miles per gallon more than it is getting. With a similar efficiency gain across the entire transportation sector, the oil savings would be 2 million barrels per day, exceeding our pre-Gulf-crisis imports from Iraq, Kuwait and Saudi Arabia!

The risks

America took outlandish risks, and the world has paid an outlandish price, to preserve US control over Mideast oil. Before it ended, science-based technology had helped bring the war to its most gruesome phase:

US fuel-air explosives and napalm. Although there was a lot of talk and fear (but no use) of Iraqi gas weapons, these US weapons are more hideous against troops. Troops can protect themselves against toxic gas but not against incineration from dispersed explosive gases or jellied gasoline.

Iraqi gas weapons. These would have been a violation of international law and civilized norms, although America was slow to point this out when our ally Iraq gased 5000 Kurds during the Iran-Iraq war.

Civilian deaths. Scud missiles killed four Israelis. Iraqi troops executed many Kuwaitis. The US raid on the Amiriya air raid shelter in Baghdad alone killed several hundred civilians. Furthermore, "Newsweek has learned that allied intelligence previously identified the bunker as one of perhaps two dozen meant to shelter Saddam's inner circle, the leaders and families of the — ruling Baath Party" (special report in Newsweek 25 February, p. 20, emphasis added). Contrary to our government's assurances that we would not have bombed the shelter had we known civilians were present, we knowingly and purposely killed several hundred civilians.

Military deaths. Some 100 American soldiers died. Some 100,000 Iraqi soldiers died during the six weeks of US bombing. I grieve for each Iraqi death just as for each American death. Neither the Iraqi nor the American troops asked for this war. Early in the bombing campaign, surrendering Iraqi troops were stumbling into American lines mumbling "bombing, bombing, bombing —." Of course military deaths are a necessary consequence of war. And of course America cannot be faulted for this killing, given that we were at war. That is my point: America should not have been at war because, for one thing, it was not worth the 100,000 Iraqi deaths.

Israel's entry into the war. Although this did not occur, it was always a real possibility. It was a risk of the war. It could have spread the war and further destabilized the entire region.

Environmental destruction of the Gulf and damage to water supplies. Contrary to Bush's description of the Iraqi oil spills as "pure environmental terrorism with no military purpose," the spills had the purpose of fouling the Saudi desalinization plants. Like US destruction of Iraqi water supplies, they deprived the enemy of the means (water) to fight. Throughout Iraq there is little water to drink. In Baghdad, water-borne disease has gained a foothold.

Burning of oil fields. Scorched-earth tactics are as old as warfare, and as recent as US raids over Vietnam. The smoke of Kuwait's oil also had the military effect of reducing the efficiency of US air power. We knew long ago that Hussein had wired the wells for destruction. The fires have grave environmental implications, including additional greenhouse loading of the atmosphere. Was this predictable destruction figured, in advance, into the risks of the war?

Nuclear weapons. America has about 1000 nuclear weapons in the Gulf, mostly on ships. "According to two well-informed sources — Gen. Norman Schwarzkopf requested authorization to explode a nuclear device high over Iraq at the start of hostilities. Such a blast would generate a massive electromagnetic pulse, which would shut down every electronic device in Iraq. One source said that the request had gone as high as President Bush, who rejected it" (*Newsweek, 14 January* 1991, p. 17). The Pentagon studied earth-penetrating nuclear warheads, and neutron shells, for possible use in the war. 45 % of Americans favored nuclear weapons "if it would save the lives of US troops." Otherwise intelligent politicians, such as my own state's Senator Dale Bumpers, have described neutron shells as "a measured response" to a chemical attack. Secretary of Defense Cheney, speaking of an Iraqi chemical attack, stated that "the possibility would then exist, certainly with respect to the Israelis, for example, that they might retaliate with unconventional weapons as well." For the Israelis, and probably for America as well, an "unconventional response" can mean only nuclear weapons.

US control of Mideast oil was not worth the risks, and not worth the actual costs.

To the Forum: Do not be silent

It is a popular liberal notion that, although we perhaps should not have gone to war, once we were in it Americans had little choice but to support the President and support the war, or at any rate to refrain from opposing the war or trying to change the policy. I disagree.

Similar arguments have always supported the irrational decisions of national leaders, especially in times of war. Such arguments were made by the "good German" intellectuals during both world wars (note Einstein's dissent, above), and were raised against dissent during the Vietnam War. Recall that it was not the intellectuals, nor the scientists, nor even the adults who protested and eventually ended our misbegotten adventure in Vietnam. It was young people who showed the way. Not being intellectually sophisticated, they did not understand that a national decision for war cannot be protested. Not being cooly realistic, they did not realize that their protest made no difference. Being thus naive, they protested the policy and they helped force a US withdrawal.

Thank God for those naive children, the true realists, who shortened the tragedy of Vietnam. We scientists and we adults should have been quicker to follow their lead.

I call on my fellow scientists to follow their own minds and hearts, rather than government policy or the arguments of those who would dissociate science from morality, regarding the great science-related moral issues. If we believe that a policy is wrong, let us be unafraid to say that it is wrong, unafraid to take action against it. In these times, made so dangerous by the power of science and technology, scientists must not be silent.

Art Hobson